original Foucault interrupter, the current being conveyed from one mercury pool through a copper dipper,

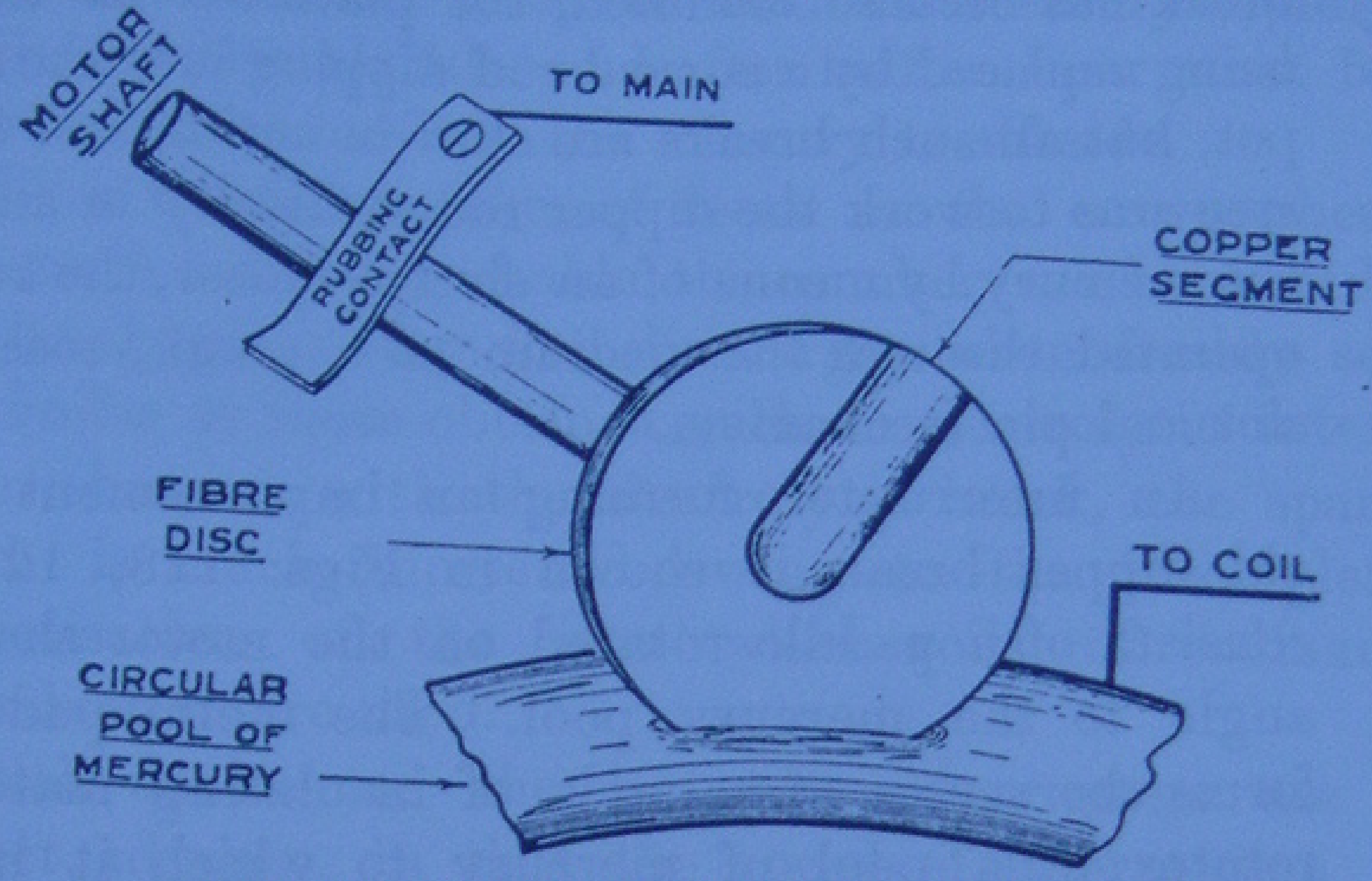


FIG. 128.—Mackenzie Davidson break (diagram).

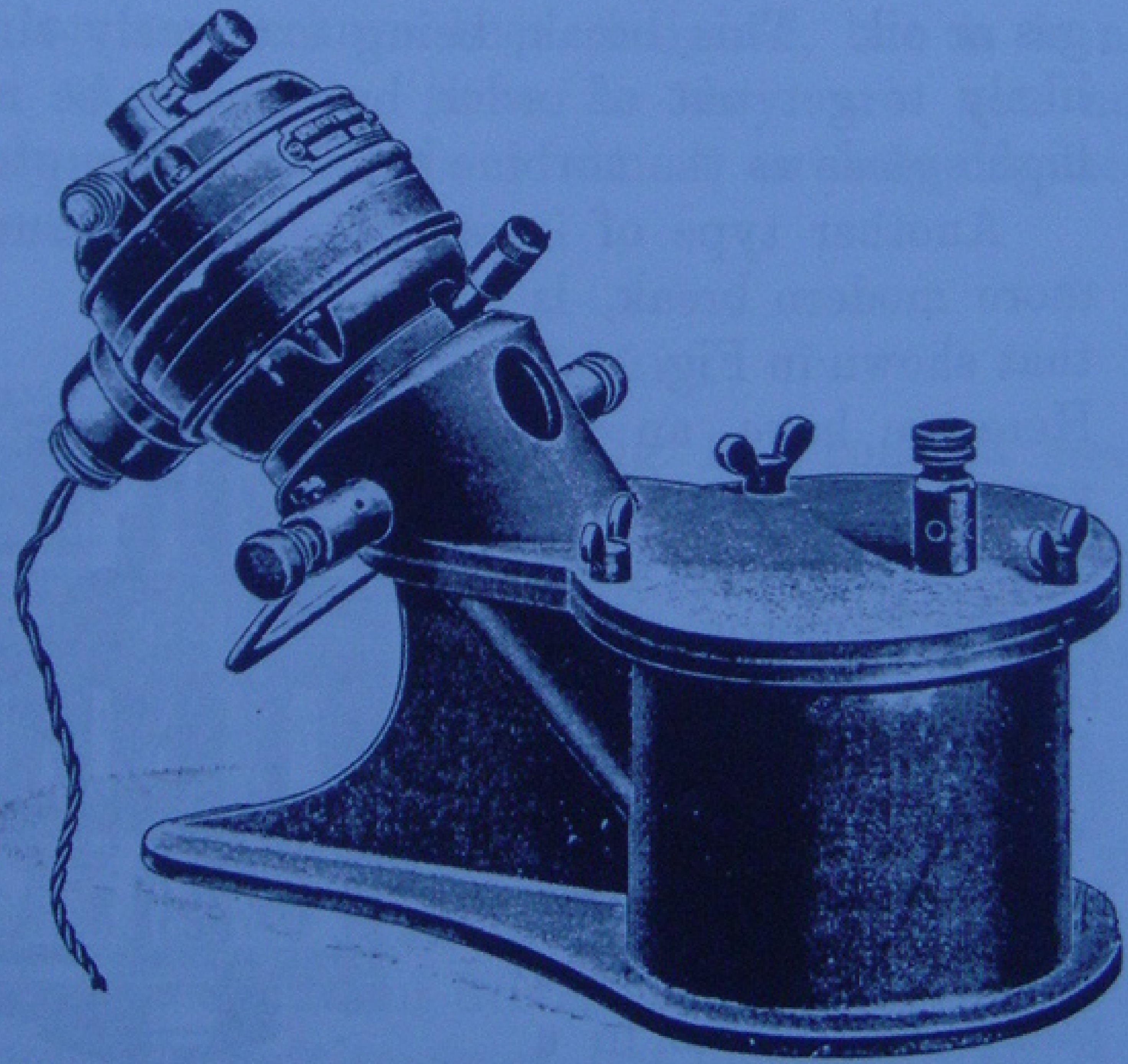


FIG. 129.—Mackenzie Davidson break, general appearance.

which does not leave the mercury, back to the second dipper, which serves as the true interrupter.

Sometimes the mercury break is arranged to be operated by the magnetism of the core itself. Apps' break has been so modified, the platinum on the blade being replaced by a curved rod dipping into the mercury pot, but all such breaks are slow in action and the next step was to work the dipper rod vertically in and out of the mercury by means of an electro-motor, the rod being operated through the medium of a crank, eccentric, or slot and pin mechanism.

An interrupter forming an improvement on the old dipper break is shown in Figs. 128, 129. This consists of a paddle rotated on the motor shaft at an angle to the mercury pool. The metal paddle itself forms the sector of a circle of insulating material and rotates in a pool of mercury to which it imparts a rotary movement. The dielectric used can be either gas or oil. This break, being extremely simple, is not likely to get out of order, but cannot be run at such high speeds as the turbine type of interrupter.

Another type of interrupter, the forerunner of the more modern break, is that shown in Fig. 130. Here we have an inverted crown wheel driven by a belt from a small motor. The bottom of the shaft drives a small toothed wheel pump submerged in mercury. The outlet from the pump terminates in a movable nozzle from which the issuing jet of mercury impinges on the rotating teeth of the crown wheel. The jet being movable in a vertical direction can play on the teeth

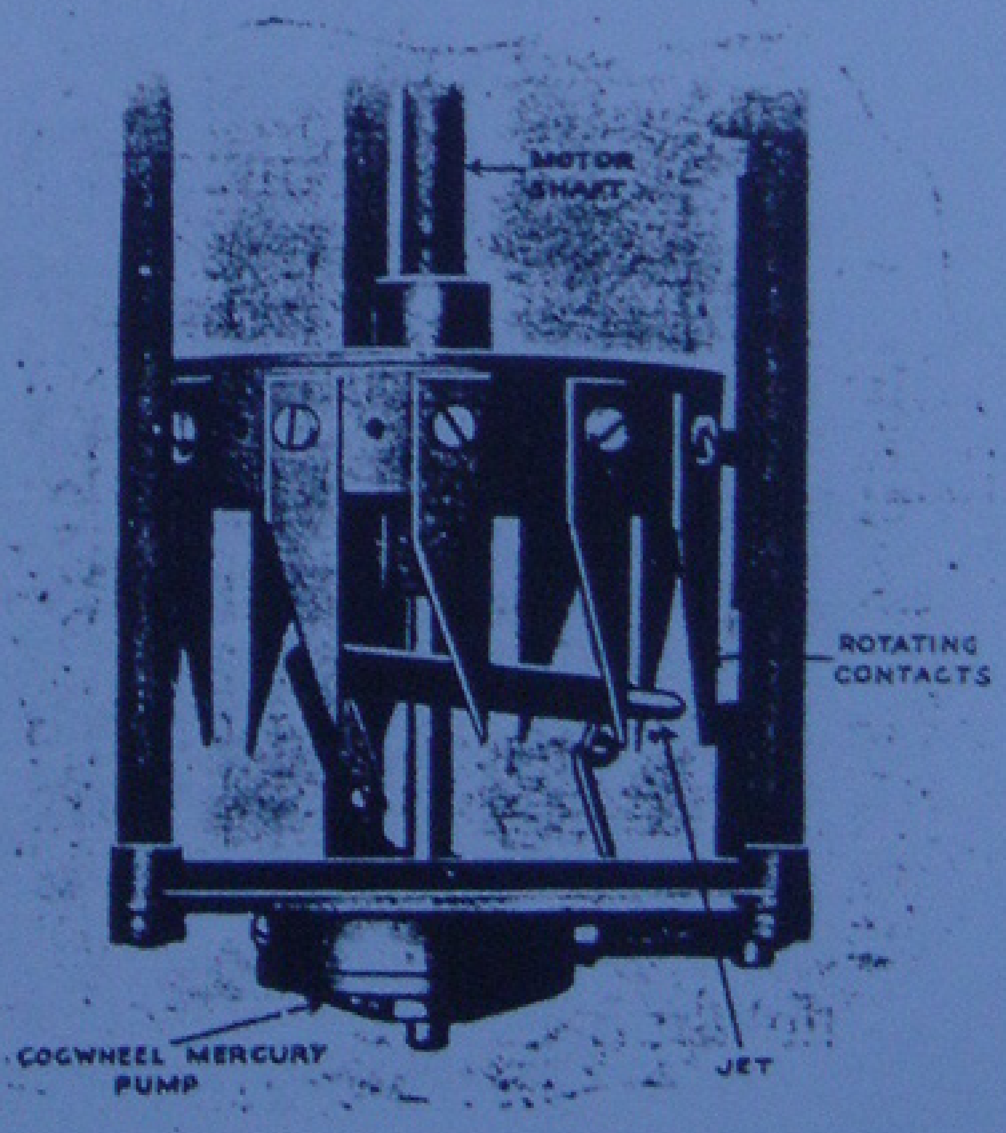


FIG. 130.—Max Levy interrupter.

anywhere from the tips to the root, thereby varying the period of contact. The interrupter runs either in a gas or oil dielectric, but if oil be used the mercury rapidly subdivides into globules and after half an hour must be allowed to rest to allow the mercury to subside.

With the full number of teeth on the crown wheel (the teeth being detachable the number can be varied) this break gives very fine discharges when freshly set up, similar to those obtained with an electrolytic interrupter, but, as with the electrolytic break, the spark length is much shortened owing to the incomplete magnetisation of the iron when coils of ordinary self-induction are used.

Such devices as the last two interrupters are a distinct advance, in that the speed of interruption is more directly under control, and many variations in the form of apparatus have been designed, but it is not proposed to illustrate these as they are not now commonly used, having been almost entirely displaced by the more modern breaks.

TURBINE BREAKS.

The turbine break proper (Fig. 131) consists essentially of a cast-iron pot, which should be large to dissipate the heat generated by the interruption of large currents and sufficiently stout to resist occasional explosions due to accidentally weak gas mixtures.

The top of the pot (Fig. 132) is usually closed by an ebonite cover attached by thumbscrews to make a gas-tight joint, on which is mounted the electro-motor.

The shaft of the motor drives a second shaft protruding through this ebonite cover, but insulated from it by an ebonite or fibre sleeve to prevent any chance extra current breaking down the motor windings. The shaft in the pot carries a cone, usually of iron or wood, drilled with two passages terminating in two iron nozzles which are arranged to protrude from the top of the cone at opposite ends of a diameter. The bottom of the cone

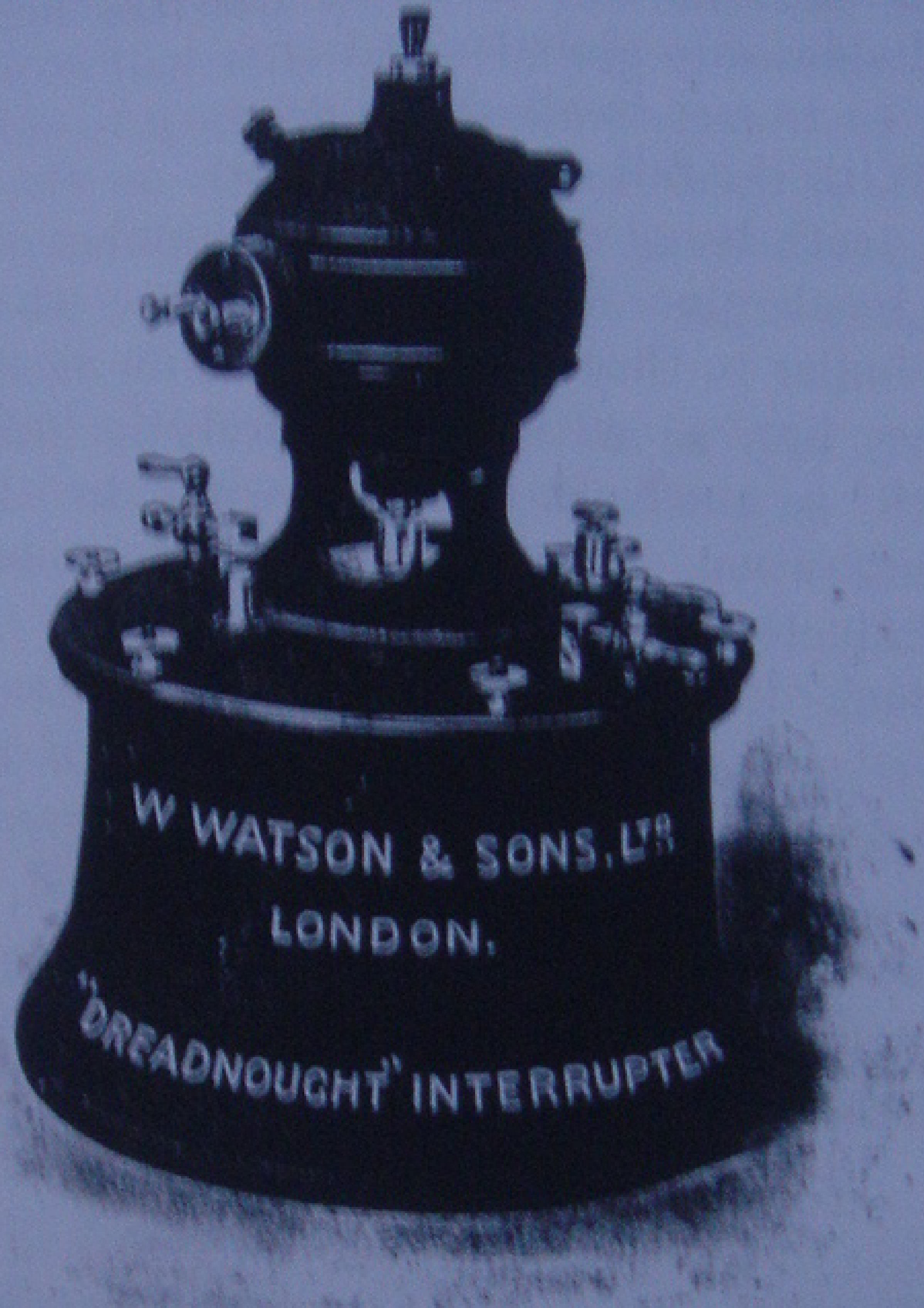


FIG. 131.—Mercury turbine interrupter, assembled.

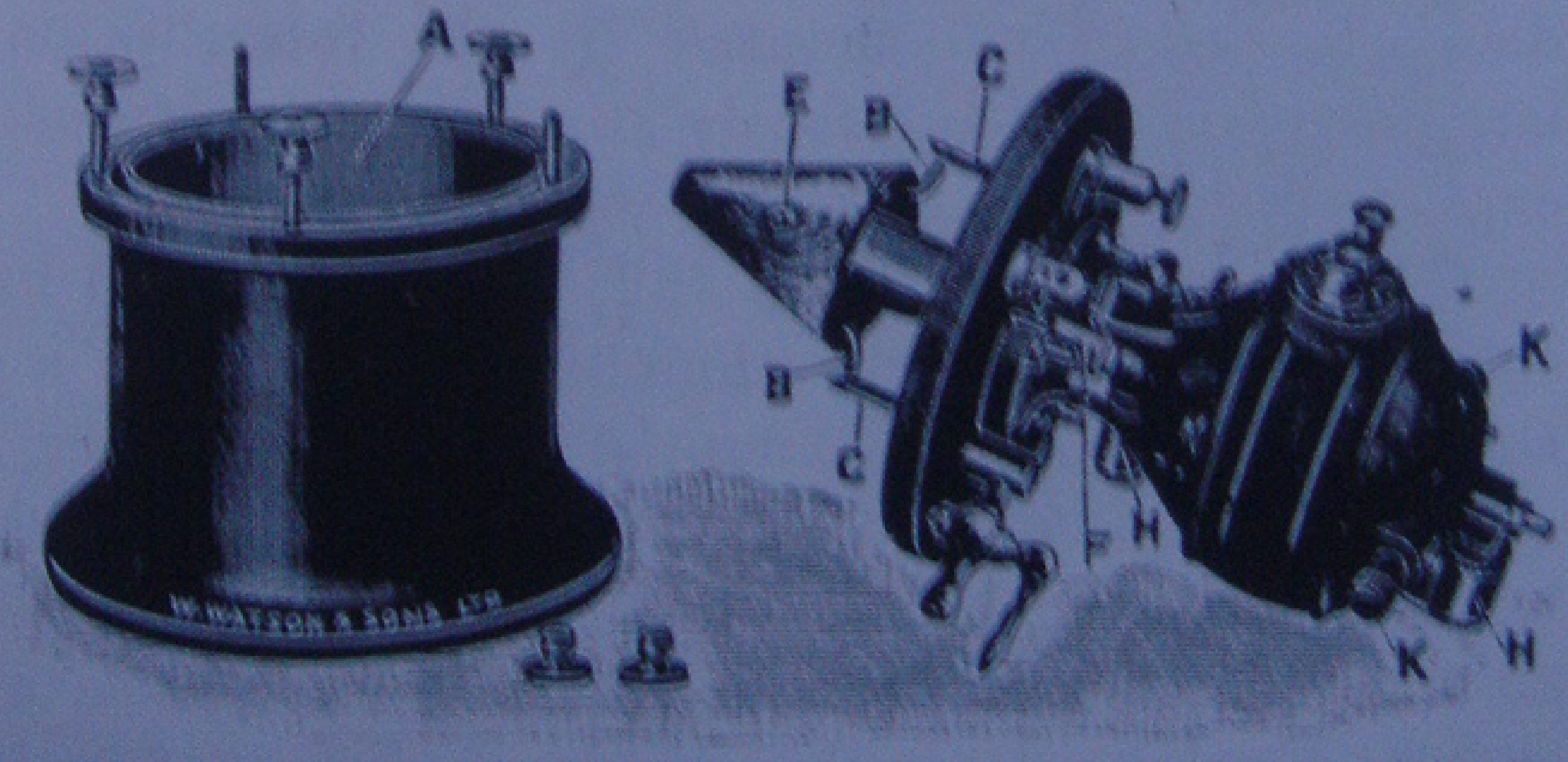


FIG. 132.—Mercury turbine interrupter, taken apart to show mercury jet coils and contacts.

A, Mercury pot. B, Jets. C, Contact segments. E, Jet cone. F, Coupling sleeve between cone and motor. H, Lubricators. K, Motor brushes.

is immersed in a pool of mercury which rises in the passages in the cone by centrifugal force and sprays out from the nozzles in jet form. Arranged concentrically with the jets and about $\frac{1}{16}''$ distant are the contact segments, usually of copper, against which the jet of mercury impinges. The circuit is thus from one segment through the column of mercury, the mercury pool, and the second column of mercury to the second segment. Each revolution of the motor thus gives two interruptions.

Should the motor for any reason fail, the mercury falls in the jet passages and the circuit is automatically broken ; there is thus no danger of burning out the coil or blowing the fuse, and accidentally switching on the main current without first starting the motor will produce no ill effect. In order to vary the duration or length of contact in these interrupters the usual method is to make one of the two contact segments triangular in shape, this segment being movable in a direction normal to the plane of the jets. Thus, when fully depressed, the jet sweeps the whole contact area and, when nearly fully raised, only the apex of the triangle. In this way any desired duration of contact can be obtained. Some makers provide fixed contacts only, the interrupter being tuned to the particular coil for which it is supplied, but generally speaking this is not desirable, the additional refinement of adjustable contact length being necessary to obtain the best time economy under varying conditions. Occasionally four contacts are arranged in the circle, thereby giving four interruptions per revolution. Such an arrangement is usually found where the pressure of the mains is high and the self-induction of the coil abnormally low.

Another method of varying the length of "make" is shown in Fig. 133. Here we have the mercury jet device rotating as before, but the mercury impinges on a sector free to hinge about one extremity. By swinging the blade more or less from its true centre the time of contact can be varied at will, as when the sector is truly concentric the jet sweeps the whole length of the blade, but when swung fully out only that part adjacent to the pivot. It is claimed, moreover, for this device that the circuit is closed gradually through the mercury column which decreases in resistance as the nozzle relatively approaches the sector, thereby diminishing the likelihood of inverse current being developed.

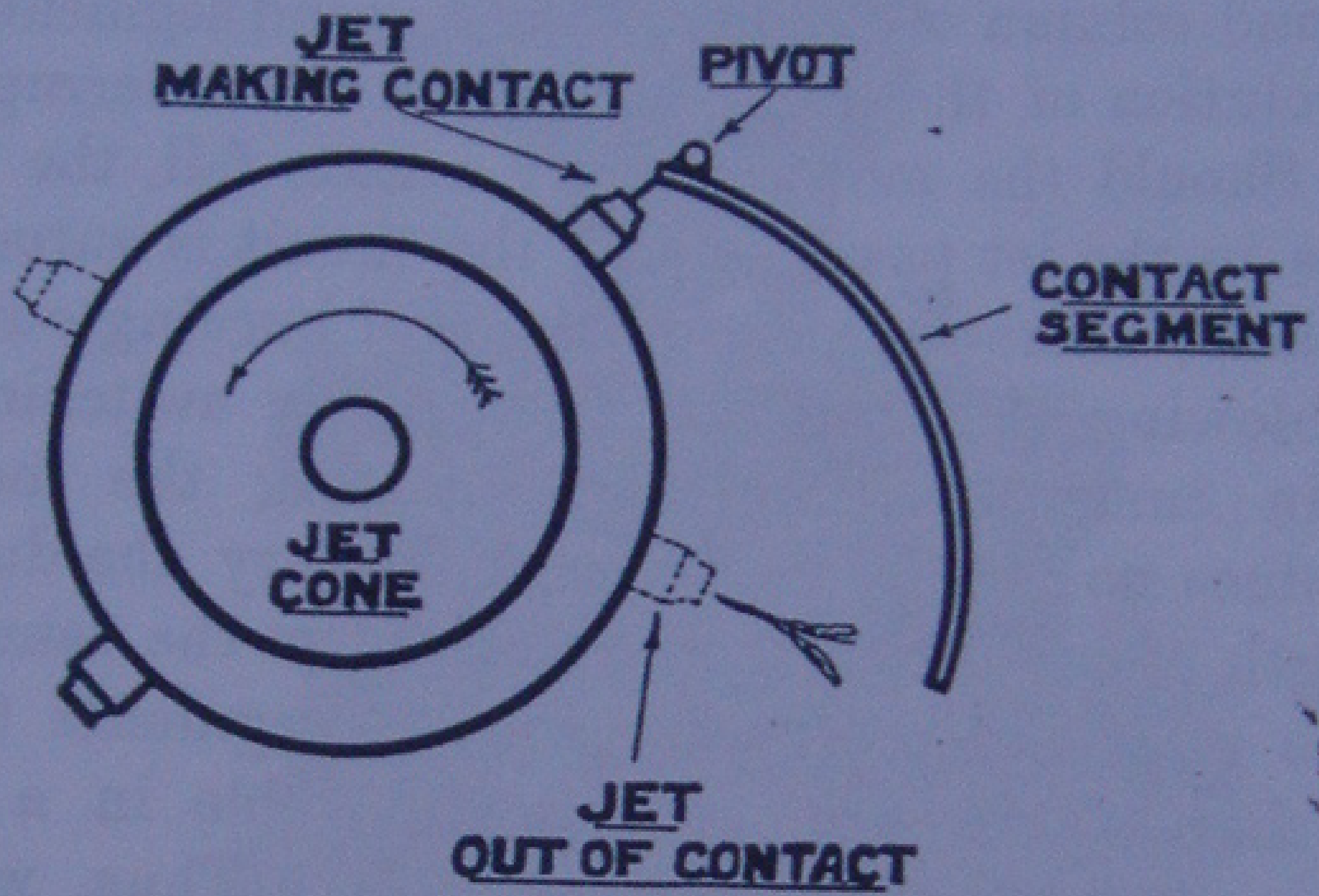


Fig. 133.—Variable contact segment.

In many portable coils an arrangement similar to Fig. 134 is employed in place of the old vibrator interrupter, the motive power being, as before, the magnetism of the iron core which is used to attract a rotating iron armature, which takes the place of the usual electro-motor. The device is started by spinning with the fingers. The mercury rises in the jet passages

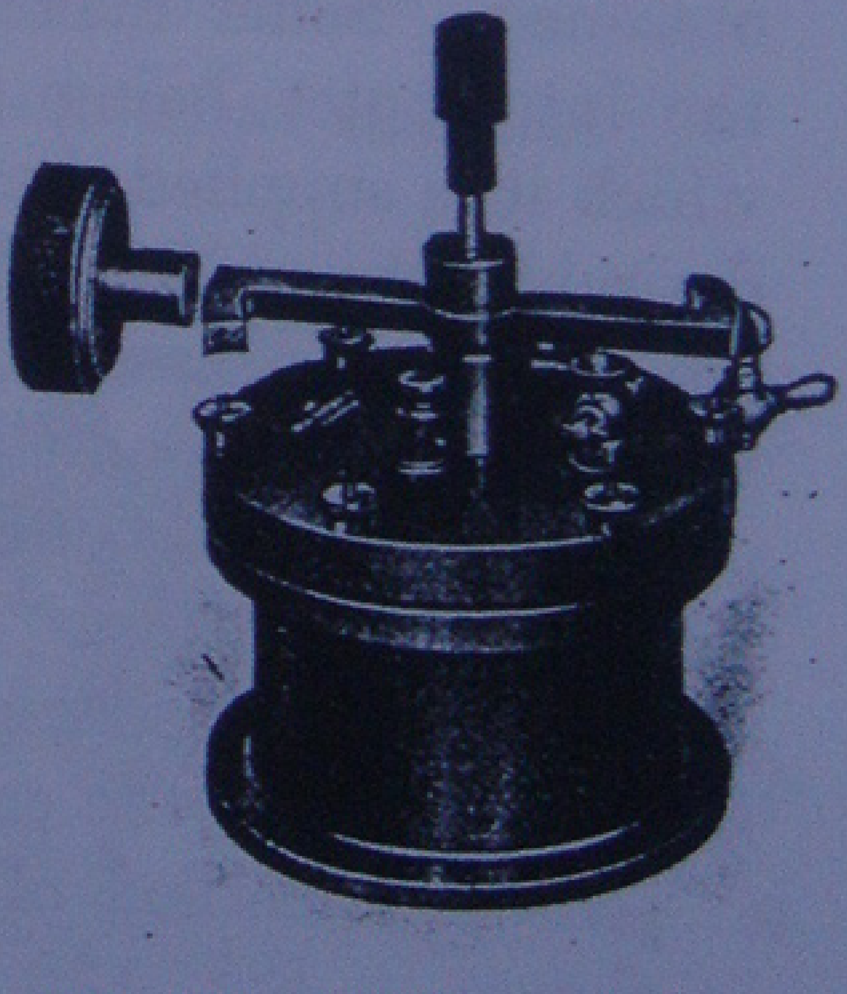


Fig. 134.—Mercury auto-interrupter.

and completes the circuit whereon the iron armature is attracted to the core. Precisely at the moment the armature is opposite the core the mercury jet is arranged to interrupt the circuit, and, the magnetism ceasing, the momentum of the armature causes the mercury cone to continue revolving until the circuit is again closed, and so on. Such an auto-interrupter is a great advance on the old platinum break, but it is not very flexible and its speed varies as the voltage increases. It is therefore necessary to vary the number of layers of primary or else to use a series resistance.

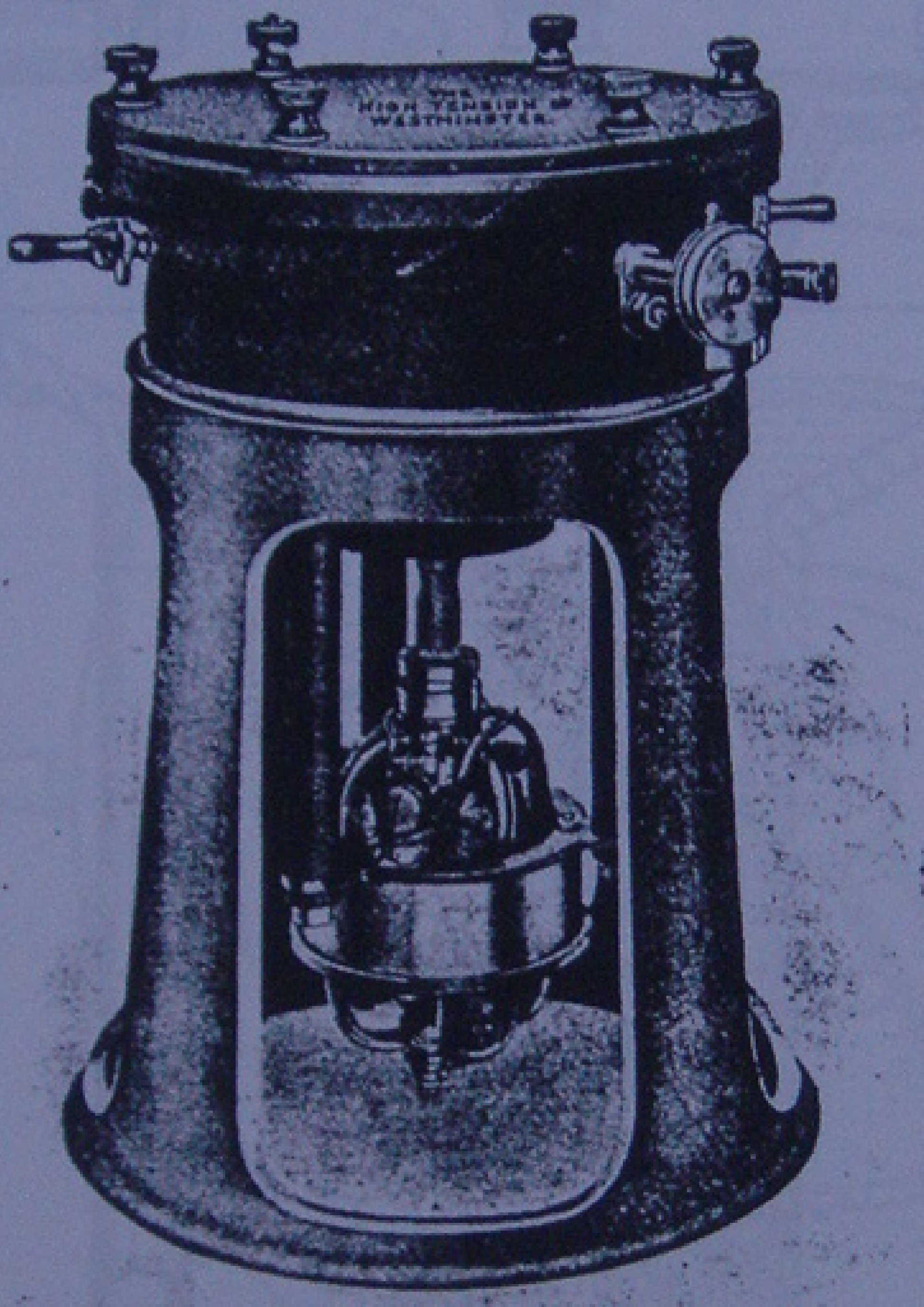


Fig. 125.—Motor under driven mercury interrupter.

Figs. 135 to 138 show an interrupter having several points of novelty.

In this design of interrupter the cone and jets are of cast iron, the cone being driven from a motor located below the mercury pot, instead of above, as is the usual practice, the bearing being a long sleeve screwed into the bottom of the pot. The base of the cone dipping into the mercury floats thereon, so that the weight of the jet cone is not taken by the bearing and an efficient gas seal is provided. The contacts are two copper segments, as usually arranged, but one is free to tip up in a vertical direction, being controlled by an ebonite hand wheel outside the mercury pot, hence the arc of contact can be varied as desired. A triplex glass lid can be fitted instead of the usual cast-iron cover so that the action of the interrupter can be viewed from without. The chief advantage of this arrangement, besides the visibility, is the ease with which the jet device may be inspected, as the jet cone can be taken out by merely removing a milled nut and the contact segments can be cleaned

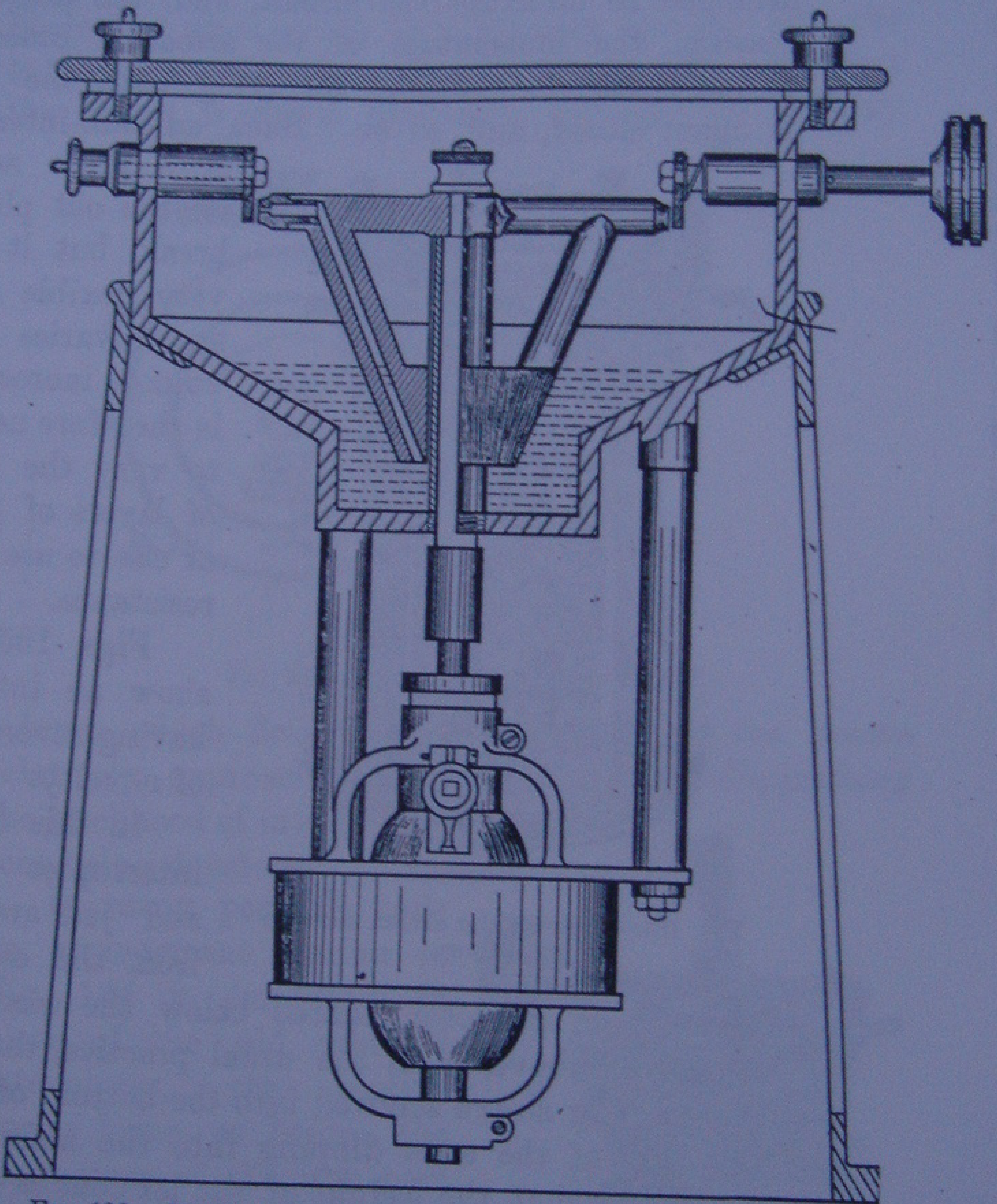
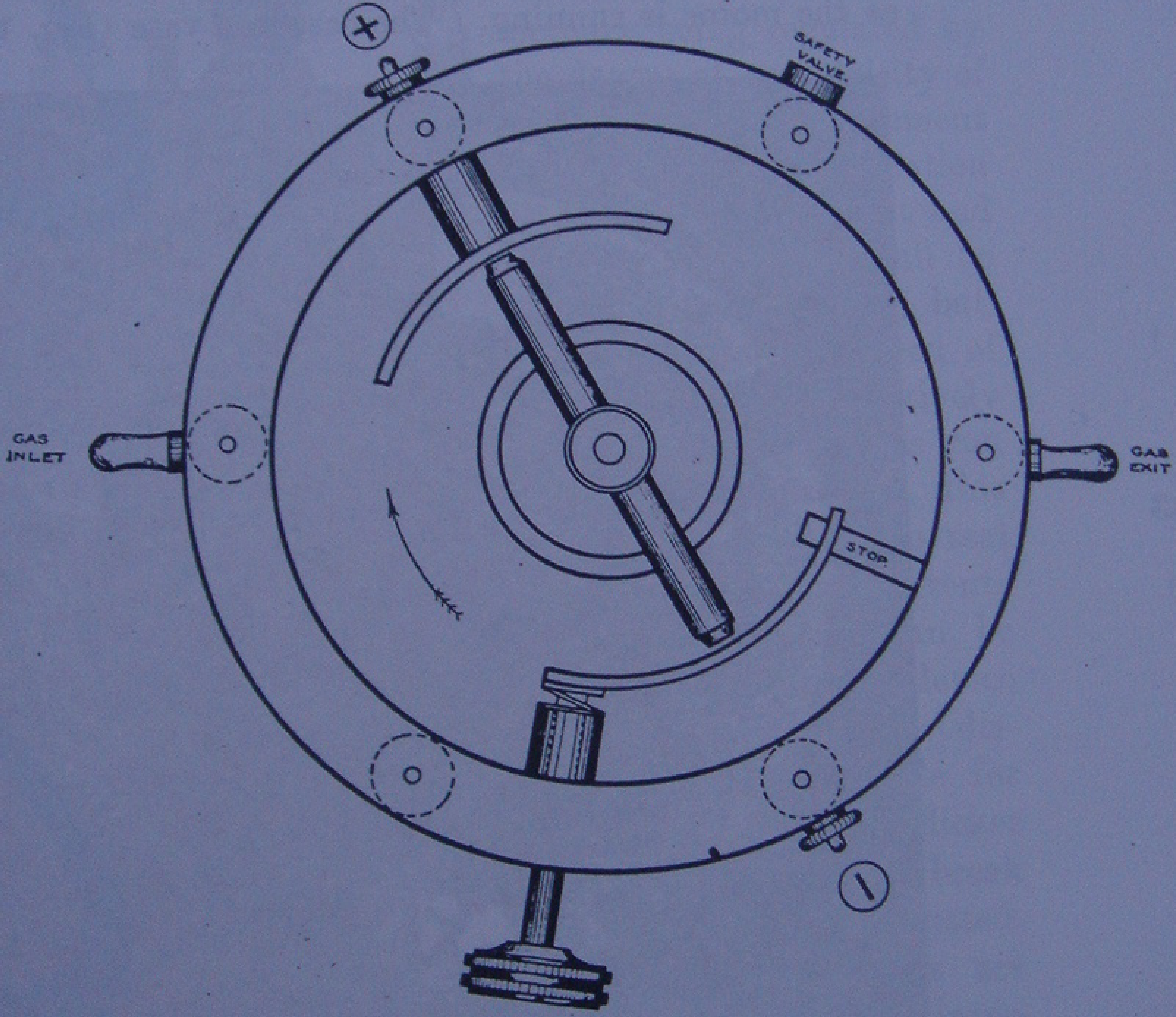


FIG. 136.—Motor under driven mercury interrupter, sectional arrangement.

without lifting the motor or detaching the motor connections, as is usually the case.

The method of driving the jet cone from beneath was first suggested by Major C. E. S. Phillips in the *Proceedings of the Physical Society*, and independently designed by the writer with the addition of the movable contact segments. It was not until some time



Plan. Time economy of contacts ·5.

FIG. 137.—Motor under driven mercury interrupter.

afterwards that the similarity of the arrangements was discovered and brought to the writer's notice.

The latest form of this break is designed to run on the 440-volt mains and will handle up to 12 K.V.A.

A type of interrupter based on an entirely different principle is the Tesla (Fig. 139). Here the vessel containing the mercury is vase-shaped, and is itself rotated by the motor which is situated below it. The effect of this rotation is to cause the mercury to rise in the cast-iron vase and form a ring of mercury at its greatest diameter, where it is retained by centrifugal force as long as the motor is running. The cast-iron vase (Fig. 140)

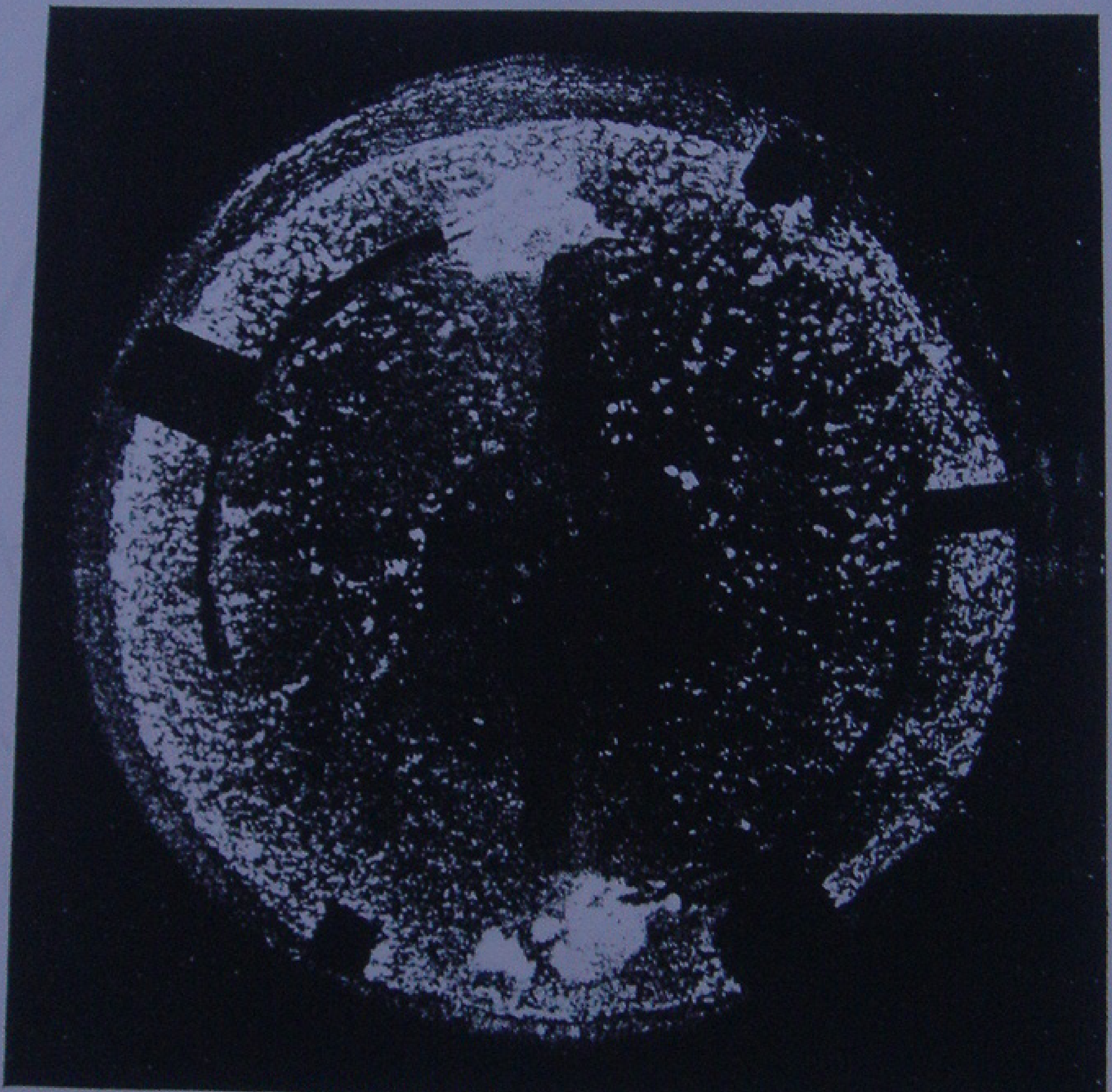


FIG. 138.—Photo of arc at contacts while working.

and the mercury form one pole of the apparatus, and to complete the circuit intermittently a fibre wheel, roughened with toothed indentations and carrying a copper segment (Fig. 140), is introduced about the centre of the vase, being allowed by suitable eccentric gear to dip more or less deeply into the rotating ring of mercury. The diameter of the ring of mercury being very much larger than that of the fibre wheel the speed of the latter is considerable, the arrangement resembling somewhat an epicyclic gear. The result is that the copper segment, rotated as part of the fibre wheel, dips into and leaves the mercury with considerable velocity, the duration of its stay beneath the surface of the mercury being regulated by the degree of eccentricity of the spindle. The movement at the point of separation of the copper segment and the ring of mercury will be a rolling motion only, but, as the peripheral speed of the apparatus is relatively high and the contacts run immersed in paraffin, this appears to present no real disadvantage, as currents up to 15 amperes can be interrupted with this device and particularly fine discharges obtained, while for screen work hardly a flicker can be observed if the break is clean and well adjusted. If too heavy currents are used, however, the interrupter is liable to spue out the paraffin and make a very objectionable mess. Owing to the centrifugal action on the mercury it does not appear to split up into minute globules as do other oil-quenched (and to a certain extent gas-quenched) breaks, and no emulsion is formed

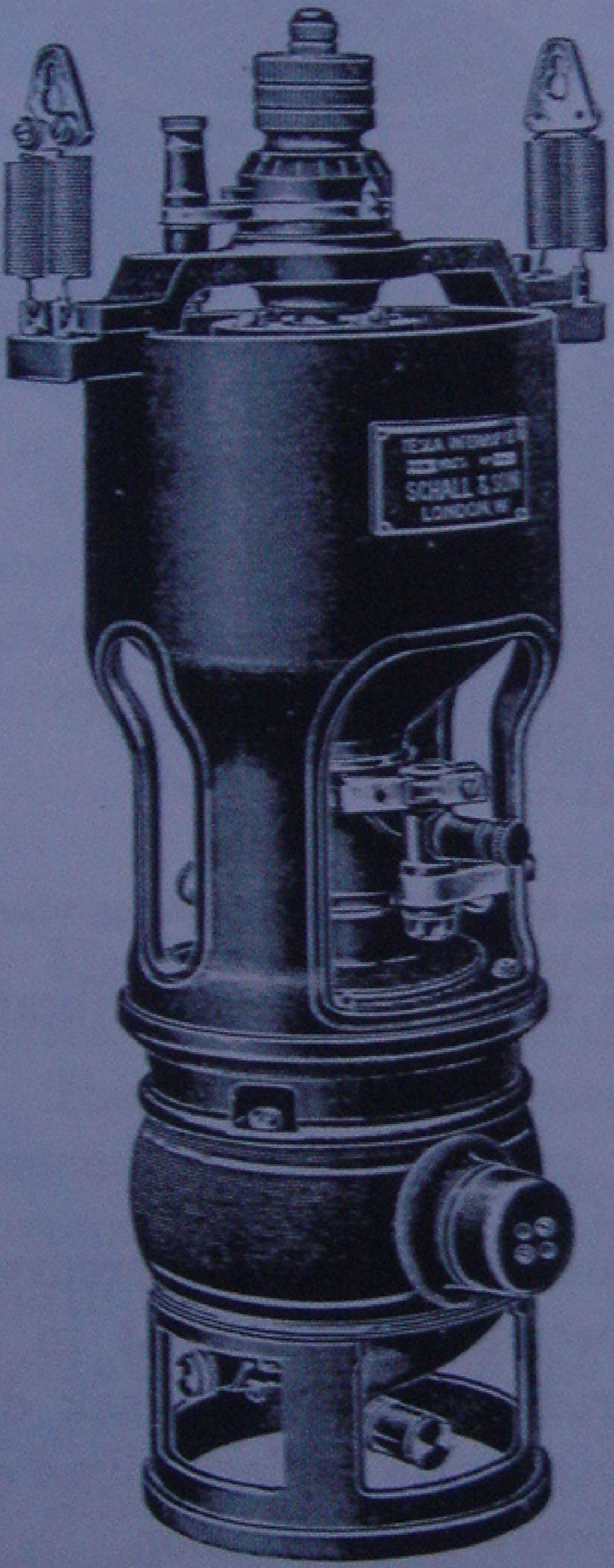


FIG. 139.—Tesla interrupter.

other than that due to the natural oxidation of the mercury. As is usual with turbine type breaks, when the device comes to rest the circuit is automatically broken. The apparatus is frequently suspended on spiral springs to reduce the noise due to the vibration of the motor.

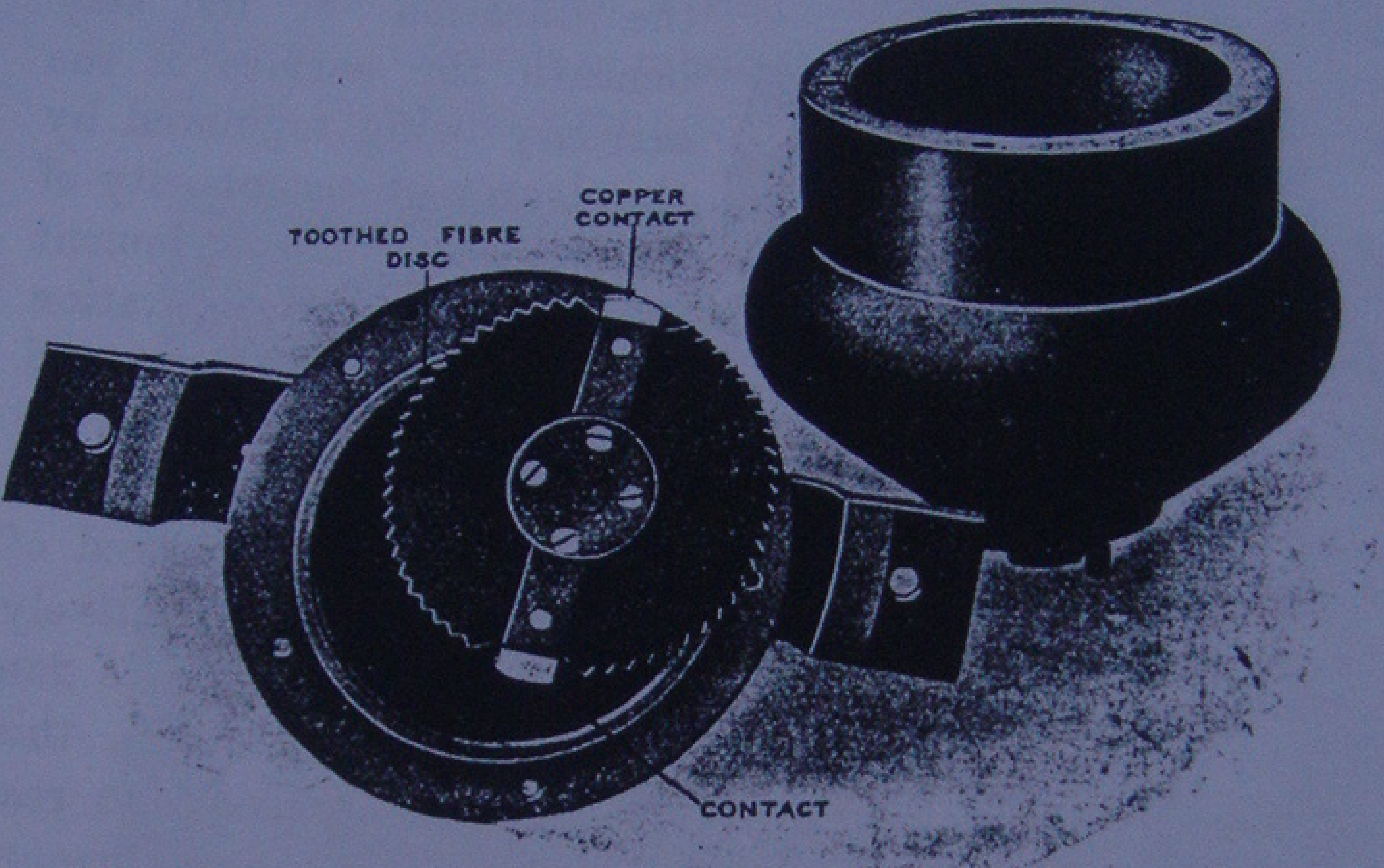


FIG. 140.—Tesla interrupter, showing mercury vase and rotating wheel.

TREATMENT OF MERCURY.

As we have already mentioned, the mercury in interrupters after a time becomes dirty, that in gas interrupters becoming covered with a grey-black dust, and in oil-quenched interrupters with a black slime containing beads of metallic mercury in suspension.

Mercury dirtied in a gas break should be washed in an earthen pot with clean water first, then with benzine or petrol, stirring the while to bring the surface of the mercury well into contact with the spirit. This washing must be repeated till the mercury is quite clean, when it should be filtered through two or three thicknesses of close linen or through chamois leather.

Mercury from an oil break is much more difficult to clean. First empty the mercury and the black sludge (which may contain a quantity of mercury in suspension) into an earthenware jar, and add paraffin, stirring the while. Empty the paraffin, and repeat, till the mercury settles to the bottom of the pot. Then use petrol or benzine till the mercury is thoroughly clean, when it should be strained as before. Despite careful washing the mercury will not amalgamate sometimes, and it may be necessary to wash it with a hot solution of caustic soda, then rinse with water and wash again with fairly strong nitric acid, in all cases stirring the while vigorously to expose the surface of the mercury to the cleansing solution.

Before returning the mercury to the break care should be taken to ascertain that the iron pot of the interrupter is quite clean and free from particles of foreign matter that might stop up the jet orifices.

Electrolytic Interrupters.

Electrolytic interrupters may be divided into two classes, the Wehnelt and the Caldwell.

The first consists essentially of a platinum wire protruding slightly from a glass or porcelain sheath immersed in diluted sulphuric acid, this platinum wire constituting the anode. The cathode consists of a lead plate also immersed in the solution, but of comparatively large area (Fig. 141). When this interrupter is connected in series with a coil having a primary winding of ordinary self-induction a series of phenomena are observed. Starting first with a low voltage and at ordinary room temperature the apparatus does not begin to function till the voltage is raised to about 12–14 volts, at which point a thin static spark will pass between the gap points if not too widely separated. At